Landfire: Landscape Fire and Resource Management Planning Tools Project

Kevin C. Ryan[1], Kristine M. Lee[2], Matthew G. Rollins[3], Zhiliang Zhu[4], James Smith[5], and Darren Johnson[6]

Abstract*—Managers are faced with reducing hazardous fuel, restoring fire regimes, and decreasing the threat of catastrophic wildfire. Often, the comprehensive, scientifically-credible data and applications needed to test alternative fuel treatments across multi-ownership landscapes are lacking. Teams from the USDA Forest Service, Department of the Interior, and The Nature Conservancy are completing the LANDFIRE Project, which produces consistent and comprehensive spatial data describing vegetation composition and structure, wildland fuel, historical fire regimes, and ecosystem status across the entire United States. LANDFIRE provides a scientific foundation for assessments of wildland fuel conditions, fire hazard, and ecosystem status. While LANDFIRE products will fill immediate needs for testing alternative fire management scenarios, planning fuel treatments, and allocating resources, the data and models have much broader applications in research, biodiversity conservation, and strategic forest and resource management planning. This paper provides a synopsis of the background, objectives, and deliverables of the LANDFIRE Project and the management challenges LANDFIRE products address. Presented are potential applications of LANDFIRE data for use in fire research and vegetation ecology studies and in wildland fuel treatments and restoration projects to protect communities at risk.*

Introduction

LANDFIRE is a five-year wildland fire, ecosystem, and wildland fuel mapping project that generates consistent, comprehensive products describing vegetation, fire, and fuel characteristics across the United States. Wildland fire managers faced with requirements for reducing hazardous fuel, restoring historical fire regimes, and decreasing threats of catastrophic wildfire are often without adequate, scientifically credible data to support their planning and decision-making processes. LANDFIRE was conceived to fill this need. The main objective of LANDFIRE is to generate relevant, integrated geospatial products that provide a scientific foundation for landscape fire management planning, prioritization of fuel treatments, interagency collaboration, community and firefighter protection, and effective resource allocation. The consistent and comprehensive nature of LANDFIRE methods ensures that products are nationally relevant, while the 30-m grid resolution assures that data can be locally applicable.

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[1] LANDFIRE program manager, at the USFS Rocky Mountain Research Station, Missoula Fire Sciences Laboratory, Missoula, MT. kryan@fs.fed.us

[2] LANDFIRE program analyst, at the USFS Rocky Mountain Research Station, Missoula Fire Sciences Laboratory, Missoula, MT.

[3] LANDFIRE science lead at the USFS Rocky Mountain Research Station, Missoula Fire Sciences Laboratory, Missoula, MT.

[4] Senior remote sensing scientist at the USGS Center for Earth Resources Observation and Science, Sioux Falls, SD.

[5] LANDFIRE program manager at The Nature Conservancy, Jacksonville, FL.

[6] Northeastern LANDFIRE modeling lead at The Nature Conservancy, Fort Andross, Brunswick, ME.

Background

The recent United States laws and policies with respect to health and restoration of wildlands share common themes. These include the recognition that 1) fire is a landscape-level biophysical process critical to the maintenance of ecosystem function; 2) solutions to fuel and fire problems require collaboration among stakeholders at all levels of government; and 3) effective collaboration requires consistent, comprehensive, up-to-date data on vegetation, wildland fuel, and fire conditions across the entire country.

In the aftermath of the 1994 fire season — in which 34 fire fighters lost their lives, dozens of communities were threatened, and hundreds of thousands of hectares burned — the Secretaries of Agriculture and Interior adopted a new federal wildland fire management policy directing federal land management agencies to manage wildland fuel and fire on an interagency, landscape-scale (USDA and USDI 1995). Through this policy, fire managers were directed to develop long-term fire management plans that incorporate measures to treat fuel and increase the utilization of biomass. Additionally, this policy called for the implementation of fire behavior prediction to support both strategic planning and tactical suppression and logistics decisions, with special consideration of firefighter safety. Clearly, fire behavior and effects modeling and information system technology play a critical role in all future wildland fire planning and management activities.

In 2000, Congress mandated the implementation of the National Fire Plan (USDA and USDI 2000). The National Fire Plan is a long-term commitment to address problems associated with unsustainable wildland fuel and ecosystem conditions that have evolved over many decades of fire suppression and land use. The plan is based on cooperation and communication among federal agencies, states, local governments, tribes, and interested publics. To supplement the National Fire Plan, the Western Governors' Association, working with federal land management agencies, developed the 10-Year Comprehensive Strategy that directs state and federal agencies to focus high priority on treatments that protect communities and provide defensible space for fire fighters (USDA and USDOI 2001). More recently, the Healthy Forests Restoration Act (HFRA) was enacted to facilitate the reduction of wildfire risk, improve biomass utilization, protect resources, promote the systematic gathering of information on wildland fire, promote the early detection of insect and disease outbreaks, and to protect, enhance, and restore ecosystems.

Managers need for continuous wildland fuel and vegetation data at sufficient spatial resolution to run commonly used decision support tools (such as BEHAVE-Plus [Andrews and others 2005], FARSITE [Finney 1998], FlamMap [Stratton 2004], Nexus [Scott and Reinhardt 2001], and FFOFEM [Reinhardt and others 1997]) led the Wildland Fire Leadership Council, a group of senior administration executives representing all land management agencies in the country, to charter the LANDFIRE Project (see www.landfire.gov for additional project details).

Mapping Vegetation and Fuel

The three general production objectives of LANDFIRE are 1) mapping existing vegetation, 2) mapping wildland fuel, and 3) mapping the departure of current landscape conditions from those that existed historically. Maps describing environmental site potential and existing and historical vegetation are important intermediate LANDFIRE products for assessing wildland fuel conditions and evaluating departure from historical conditions. Both of these assessments are required by federal wildland fire management policy and the HFRA. LANDFIRE describes current and historical vegetation characteristics by mapping existing vegetation (EVT) and modeling two types of potential vegetation: environmental site potential (ESP) and biophysical settings (BpS).

The LANDFIRE environmental site potential (ESP) product represents the vegetation that could be supported at a given site based on the biophysical environment in the absence of disturbance. As used in LANDFIRE, ESP map units represent the natural plant communities that would become established at late or climax stages of successional development in the absence of disturbance. The ESP map is similar in concept to other approaches to mapping potential vegetation in the western United States, including habitat types (Daubenmire 1968; Pfister and others 1977) and plant associations (Henderson and others 1989). It is important to note that ESP is an abstract concept and represents neither current nor historical vegetation. In LANDFIRE, ESP map units are used for site stratification in the processes of mapping surface fuel models and canopy fuel.

The biophysical settings (BpS) product represents the vegetation that can potentially exist at a given site based on both the biophysical environment and an approximation of the historical disturbance regimes. It is based on the ESP map. Unlike the ESP map, the BpS map represents natural plant communities that would become established given uninterrupted natural disturbance processes, such as fire. In LANDFIRE, the BpS map is used to link the ecological process of succession to simulation landscapes in the LANDSUM landscape fire succession model, which simulates historical fire regimes and vegetation conditions (Keane and others 2002). Each BpS map unit is matched with a model of vegetation succession and disturbance pathways, and both serve as key inputs to the LANDSUM landscape succession model. The BpS grid is similar in concept to the potential natural vegetation groups used in mapping and modeling efforts related to fire regime condition class (Schmidt and others 2002; www.frcc.gov).

The third vegetation map, existing vegetation type (EVT), represents the vegetation currently present at a given site. EVT map units are based on NatureServe's Ecological Systems classification (Comer and others 2003). The map of EVT is generated using a predictive modeling approach that relates Landsat imagery and spatially explicit biophysical gradients to field-referenced data that have been classified to LANDFIRE vegetation map units based on the dominant vegetation of the plot. Some field-referenced data are withheld from the map creation process and are used to test and validate maps and model results. To date, the LANDFIRE reference database contains approximately 146,800 field plots from the first 17 mapping zones compiled from existing government and non-government inventory databases, including the U.S. Forest Service's Forest Inventory Analysis Program.

The LANDFIRE existing vegetation maps are integrated with maps of vegetation structure to represent succession classes (termed vegetation-fuel classes in the Interagency Fire Regime Condition Class Guidebook (Hann and others 2004). Succession classes form the foundation of fire regime condition class (FRCC) calculation and represent current vegetation conditions with respect to the vegetation species composition, vegetation cover, and vegetation height ranges of successional states that occur within each biophysical setting.

LANDFIRE is mapping both surface fuel and canopy fuel. Surface fuel represents biomass that occurs on the ground contributing to the behavior of fires burning on or near the surface. Because mapping wildland fuel over large regions is very difficult using standard indirect remote sensing techniques (Keane and others 2001), the LANDFIRE Project relies on combinations of existing vegetation composition and structure and biophysical settings to create wildland fuel products. The 13 fire behavior fuel models described by Anderson (1982) and the 40 Scott and Burgan fire behavior fuel models (Scott and Burgan 2005) are mapped to facilitate the modeling of fire behavior variables such as fire intensity, spread rate, and size using models such as Rothermel's mathematical model for surface fire behavior and spread (Rothermel 1972), BEHAVE Plus (Andrews and others 2005), FARSITE (Finney 1998), NEXUS (Scott and Reinhardt 2001) and FOFEM (Reinhardt and others 1997).

Fuel models integrate the fuel characteristics necessary for fire propagation along the ground; however, additional information on the vegetation canopy is required to predict the initiation, spread, and intensity of crown fires (VanWagner 1977, 1993; Rothermel 1991; Scott 2003). Canopy fuel represents the amount and arrangement of live and dead biomass in the vegetation canopy. Maps of canopy height, canopy cover, and existing vegetation were developed using information from the LANDFIRE reference database, remote sensing methods, and statistical modeling.

In addition to canopy height and canopy density, two more canopy characteristics serve as critical components for predicting crown fire potential: canopy bulk density (CBD) and canopy base height (CBH). CBD describes the density of foliage and branches for a specific vegetated stand and is defined as the mass of available canopy fuel per canopy volume unit; canopy base height (CBH) describes the average height from the ground to a forest stand's canopy bottom. CBD and CBH were calculated for each plot in the LANDFIRE reference database using FUELCALC, a fuel summary application developed by Reinhardt and Crookston (2003). FUELCALC computes a number of canopy fuel characteristics for each field reference plot based on allometric equations relating individual tree characteristics to crown biomass. Geospatial data describing canopy fuel provide information for fire behavior models, such as FARSITE (Finney 1998), to determine areas in which a surface fire is likely to transition to a crown fire (Van Wagner 1977, 1993).

Fuel models and canopy fuel metrics are used to simulate fire *behavior*. Simulation of the *effects* of fire (such as vegetation mortality, soil heating, and smoke production) requires systems that describe and integrate the actual measurements of fuel for vegetated stands. There are two examples of fire effects models that may be produced by LANDFIRE. Both are currently under scientific review and at this time are not fully incorporated into the LANDFIRE production. Mapping of these products will be initiated upon the recommendation of scientific review. The first, fuel loading models (FLMs; Lutes and others, in preparation), use fuel information from the LANDFIRE reference database to characterize representative loading for each fuel component (for example, woody and non-woody) for typical vegetation classification systems such as the Society of American Foresters vegetation classification system (Eyre 1980). FLMs characterize fuel loading across all vegetation and ecological types. The second fire effects modeling system, called the Fuel Characterization Classification System (FCCS) and developed by Sandberg and others (2001), summarizes fuelbeds using canopy, shrub, surface, and ground fuel stratifications. Several fuelbed categories that describe unique combustion environments form the foundation of FCCS. See www.fs.fed.us/pnw/fera/research for more information on FCCS. Both sets of fire effects models are formulated to serve as input to existing fire effects models such as FOFEM (Reinhardt and others 1997) and CONSUME (Ottmar and others 1993). When incorporated into LANDFIRE production, these sets of fire effects models will be assigned to unique combinations of the integrated vegetation products. Geospatial representation of fire effects fuel models may be used to prioritize fuel treatment areas, evaluate fire hazard and potential, and examine past, present, and future fuel loading characterizations. See Reeves and others, this proceedings for a full description of LANDFIRE fuel products.

In addition to products that describe wildland fuel characteristics, LANDFIRE produces a suite of products related to fire regime condition class (FRCC). The discrete, three-level FRCC classification, established by Hann and Bunnell (2001), is defined as a descriptor of the amount of "departure from the historical natural regimes, possibly resulting in alterations of key ecosystem components such as species composition, structural stage, stand age, canopy closure, and fuel loadings." The three condition classes describe low departure (FRCC I), moderate departure (FRCC II), and high departure (FRCC III). LANDFIRE produces maps of FRCC using methods derived from the Interagency Fire Regime Condition Class Guidebook (Hann and others 2004). It is important to note that the LANDFIRE FRCC map represents the departure of current vegetation conditions from simulated historical reference conditions, which is only one component of the FRCC characterization outlined in Hann and others (2004).

The *historical* reference conditions for vegetation succession classes are simulated using LANDSUM (Keane and others 2002). The *existing* succession classes, mapped according to EVT, can additionally represent uncharacteristic vegetation components, such as exotic species, that are not found within the compositional or structural variability of successional states defined for a biophysical setting. In LANDFIRE, current succession class proportions within an analysis area are compared to those of simulated historical reference conditions to calculate FRCC.

LANDFIRE also produces maps of fire regime groups representing an integration of the spatial fire regime characteristics of frequency and severity simulated via the LANDSUM model (Keane and others 2002). These groups are intended to characterize the presumed historical fire regimes based on interactions between vegetation dynamics, fire spread, fire effects, and spatial context (Hann and others 2004). Fire regime groups mapped by LANDFIRE include: 1) Fire Regime I (0 to 35 year frequency, low to mixed severity), 2) Fire Regime II (0 to 35 year frequency, replacement severity), 3) Fire Regime III (35 to 200 year frequency, low to mixed severity), 4) Fire Regime IV (35 to 200 year frequency, replacement severity), and 5) Fire Regime V (200+ year frequency, any severity).

Applications

The consistent and comprehensive fuel and vegetation data produced by LANDFIRE provide managers and scientists with the ability to systematically compare how vegetation, fuel, and fire potential vary between landscapes. LANDFIRE provides the fuel and terrain data necessary for executing the FARSITE (Finney 1998), FlamMap (Stratton 2004), BEHAVE-Plus

(Andrews and others 2005), and Nexus (Scott and Reinhardt 2001) models. Surface fuel models include the 13 fire behavior fuel models (Anderson 1982) and the 40 fire behavior fuel models (Scott and Burgan 2005). Fuel consumption, smoke production, and soil heating calculated using FOFEM (Reinhardt and others 1997) and CONSUME (Ottmar and others 1993). LANDFIRE products provide managers with the ability to predict potential fire behavior in tactical and strategic planning of suppression activities. The ability to model expected fire behavior with and without fuel treatments provides managers with valuable decision support tools for strategic planning (Finney 2001, 2005). The ability to predict and game fire behavior and effects across landscapes provides managers and scientists with a framework to explore biophysical mechanisms that entrain fire regimes and to forecast the implications of climate change (Keane and others 1997), fragmentation (Finney 2005), and other disturbances across landscapes and regions. Finally, the ability to quantify the locations and magnitude of hazardous fuel is critical for designing defensible space and protecting communities.

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